BD-7400-172-1 (07/91)

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Document Number: WHC-SD-SQA-CSWD-300¹⁴⁹~~61~~, Revision 0

Document Title: Validation and Verification of DEPOSITION 2.0

Release Date: September 16, 1994

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9/16/94

(Date)

SUPPORTING DOCUMENT		1. Total Pages ^{USE} 18 17 9/16/94	
2. Title Verification and Validation of DEPOSITION 2.0		3. Number ^{USE} 9/16/94 WHC-SD-SGA-CSWD-30016 WHC-SD-CSWD-30016	4. Rev No. 0
5. Key Words Deposition, Line Loss, Continuous Air Monitoring, CAM, Fixed Head		6. Author Name: W. J. Eadie <i>W. J. Eadie</i> Signature Organization/Charge Code 33610/J3361	
7. Abstract This document verifies and validates the use of the computer program, DEPOSITION 2.0 for the use in assessing line loss in CAM and fixed head lines throughout certain Hanford Site facilities.			
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9. Impact Level 2SQ			

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VALIDATION AND VERIFICATION OF DEPOSITION 2.0

1.0 PURPOSE AND SCOPE

The purpose of this document is to verify and validate the usage of the computer program, DEPOSITION 2.0 for use in assessing line loss in CAM and fixed head lines throughout certain Hanford Site facilities. The scope of use is limited to this function. DEPOSITION 2.0 is the second version of this code to be used on the Hanford Site, the program now incorporates additional user-friendly features beyond those which were available in an earlier version, DEPOSITION 1.03.

2.0 INTRODUCTION

On the Hanford Site, near-real time measurements of radioactivity associated with aerosol particles are made with continuous air monitors (CAMs). Often these CAMs may be physically remote from the sampling location, in which case, aerosol particles are transported from sampling the location to the CAM through a transport system. Typically these transport lines consist of straight tubes, elbows and an inlet nozzle. If prohibitively high levels of radioactivity are recorded by a CAM, an alarm will be triggered to initiate emergency procedures. In order for the CAMs to provide meaningful signals, the loss of aerosol particles through transport lines should be at a minimum (Anand et al. 1992). The percentage of particulate penetration through an air sampling line can be determined in some degree by mathematical equations which account for sedimentation, diffusion, and inertial impaction. These equations allow for a "standardized" particle, a theoretical spherical particle with a density of one, but which has the characteristics with regards to diffusion, settling, deposition, etc. of an actual particle. The diameter of this theoretical sphere is referred to as the aerodynamic equivalent diameter (AED).

One particular aspect of this mathematical description is the ability to create computer software that can model what happens to aerosols under varied circumstances. The Hanford Site will use DEPOSITION 2.0 for preliminary characterization of how much airborne radioactive contamination is lost through the lines connected to CAMs.

The DEPOSITION program was written by faculty members of the Texas A&M University, Department of Mechanical Engineering, and is based on refinements the department has made in aerosol and particle measurement mathematics. These refinements are explained in a paper published in *Aerosol Science and Technology* (Anand et al. 1992). DEPOSITION is simple to use, and

straightforward instructions are provided by the program writers in Section 5 of NUREG/GR-0006 (Anand and McFarland 1991). The program is cited by the U.S. Nuclear Regulatory Commission (NRC) in the *Draft Regulatory Guide*, DG-8003, Paragraph 4.6 (NRC 1991), as being an "acceptable" method of assessing line loss due to deposition inside the lines. DEPOSITION is the only computer code described as acceptable. In NUREG/GR-0006, Anand and McFarland (1991) report their own validation of the program, which reaches the same conclusions as those in this document.

DEPOSITION 2.0 incorporates several new changes over that DEPOSITION 1.03, including: minor changes to the DEPOSITION code, inlet particle loss evaluation, output to ASCII files, graphical displays, calculation of wall losses in a single isokinetic sampling probe, and variation analyses of effects of changes in particle size, tube size, and flow rate.

One limitation to the program is that all input must be done by keyboard. There are other limitations to the DEPOSITION 2.0 program which are beyond the scope of this document. The chemical and physical nature of the aerosol must be known to properly use the program. The characterization of these properties is being examined by means of analysis in other phases of the line loss study. For example, particle sizes in facilities to be examined will be characterized using a cascade impactor. Particle dynamics theory implies that there is no significant differences in deposition between types of metallic pipes, such as copper or stainless steel. Tygon^a tubing plastic is another matter, however. The data associated with segments of Tygon tubing will not be run through the program and will not be dealt with through the use of DEPOSITION 2.0. It is hoped that the facilities will remove all TYGON tubing

It should be noted that this document is essentially a revision to R. H. Ruben's verification and validation of DEPOSITION 1.03 (Ruben 1992). Two test cases were imputed into DEPOSITION 2.0 and then the output was statistically compared to the empirical data for the two test cases. This method is a recapitulation of a study done by J. Glissmeyer (Glissmeyer 1991), an engineer in the Aerosol Sciences Department at Pacific Northwest Laboratory, in which he compared several computer codes of the DEPOSITION type.

The data collected and tests performed in this document have been reviewed and approved by R. H. Ruben, Senior Health Physicist for Westinghouse Hanford Company.

^aTygon is a trademark of the Norton Company.

3.0 METHOD

DEPOSITION 2.0 is meant to be used with DOS type computer. The hardware used for this program was run on a WIN 386Sx with a Hewlett Packard Laser III printer.

The input data used in evaluating this program is referenced at the end of this document. The input data was manually entered by keyboard into the program and output data was displayed on screen and then was saved as an ASCII file. The ASCII file was then incorporated into a Lotus^b spreadsheet and a SigmaPlot^c graph. All work was done by the author of this document between June 10, 1993 and June 25, 1993.

DEPOSITION 2.0 was compared with two sets of empirical data. The first set uses the results from work done for the NRC by Dr. A. M. McFarland at Texas A&M (Fan et al. 1991). McFarland's experiment used a simple air sampler that tested for various particle sizes and flow conditions when particles were aspirated from a wind tunnel. The free stream velocity in the wind tunnel was 3 m/s and the particle density was 0.9340 g/cm. The piping diameter was 26.7mm and consisted of the following:

Element 1 : Isokinetic PROBE

Element 2 : 0.610 m TUBE at 0.000 degrees from Horizontal

Element 3 : 90 degree ELBOW

Element 4 : 0.610 m TUBE at 90.000 degrees from Horizontal

Element 5 : 45 degree ELBOW

Element 6 : 0.610 m TUBE at 45.000 degrees from Horizontal

Data was generated for an inlet placed in perpendicular and axial direction to the flow of the wind tunnel.

The other set of data was taken from a report by Lars Strom (Strom 1972), where a vertical loop of 16.8 mm diameter pipe was tested for transport of various particle sizes and flow rates when the particles were aspirated from a generating chamber. The loop consisted of the following:

^bLotus is a trade mark of the Lotus Developmental Corporation.

^cSigmaPlot is a trademark of Jandel Scientific Company

Element 1 : 2.000 m TUBE at 0.000 degrees from Horizontal

Element 2 : 90 degree ELBOW

Element 3 : 2.000 m TUBE at 90.000 degrees from Horizontal

Element 4 : 90 degree ELBOW

Element 5 : 2.000 m TUBE at 0.000 degrees from Horizontal

Element 6 : 90 degree ELBOW

Element 7 : 2.000 m TUBE at 90.000 degrees from Horizontal

Data was collected with zero external wind velocity; therefore there was no consideration of an inlet.

The data obtained empirically from these studies was compared to the results from DEPOSITION 2.0 computer runs by using the same methods that Glissmeyer used (1991).

- The standard deviation of the differences between empirical and computed data
- The average difference between empirical and computed data
- Linear regression with empirical data plotted against computed data. Examination of the slope of the regression line gives an indication of how statically close the empirical observations and computed values are (a slope of one being the ideal value). The y-intercept of the regression line is also considered because both accuracy and precision are desired.

4.0 RESULTS AND CONCLUSIONS

Glissmeyer's work was intended as a comparison between several different computer codes, and this verification and validation examines only one code for purposes of determining its acceptability for use in the line loss study. Therefore similar results were analyzed differently. It should be emphasized that there are no fundamental differences in the conclusions drawn from Glissmeyer's (1991) analysis of DEPOSITION 1.02 and work done as reported in this document.

Table 1 shows the first set of test cases. Since each pair of empirical and computed data has unique set of conditions attributed to it, the data is

paired meaningfully. Therefore the statistical tests for meaningfully paired observations were used.

Table 2 shows the statistical results of the comparison between empirical and computed data. Even with the disproportionate influence of data related to particles of 20 μm AED, the numbers show good agreement between empirical and computed data. Figure 3 shows the data points listed in Table 1, along with a plot of the regression line. If the data related to AED of 20 μm are excluded, the y-intercept improves greatly. This represents the offset, or what would theoretically be computed by DEPOSITION as penetrating when there was, in actuality, 0% penetrating. The slope of the regression line also improves greatly. The extent of this improvement is shown in Table 3 and in Figure 4. The offset is effectively reduced by more than half, while the percentage that the slope differs from one is reduced by a little less than half. The elimination of data on 20 μm AED particles is feasible for two reasons. Particles of this size, once the conversion to AED is made, will represent a very small part of the samples taken in the line loss study, certainly less than 1%. Also, because the particles considered in this document are those that would cause CAMs to alarm, and the primary pathway into the body for these suspended particles is inhalation into the lower bronchi and the lungs, 20 μm particles can be virtually eliminated from consideration. Particles of this size would not travel to the lungs even if inhaled, but would instead be eliminated through the gastrointestinal system after being escalated away from the bronchi and the lungs by mucociliary action. It should be pointed out that, while up to 50 μm particles may be inhaled, only 10 μm or smaller particles reach the bronchi and lungs, and therefore become long-term dosimetric concerns.

Tables 4 and 5 and Figure 5 show the input data and the statistical results, respectively, for the second set of test data. The statistics here show much more conservative results. The offset is negative, which means that DEPOSITION would not calculate any penetration until the empirical data showed a penetration of about 8%. The slope is one, which indicates that empirical observations and DEPOSITION 2.0 computations are very close. The data for large AED particles in this set of tests show a conservative bias (i.e., for 15 μm particles, the computed values show less, in some cases much less, penetration as computed by DEPOSITION 2.0 than with experimental observations).

If either of these sets of data were to be picked to characterize the conditions expected in the line loss study, it would be the data in the Strom report (1972). All of the lines studied are inside facilities; therefore, there is no wind and no inlet to consider. The Strom's data more precisely represents the air flow rates through the lines being tested, since the air flow rates for 95% of these lines are between 50 and 65 L/min. As can be seen from Table 4, the cluster of data most representative of this air flow shows conservatism in DEPOSITION calculations.

While the differences between empirical data and computed results increase as both particle size and air flow rates increase, as long as these variables are reasonably limited, errors are acceptable. Besides, choices for alternative methods of assessing line loss through modeling are very limited. The large number of variables associated with the problem aerosol flow through a line creates a complex problem. Consequently, the mathematical methods presented in DEPOSITION 2.0 are the best available at this time.

DEPOSITION is a reasonably accurate and conservative program. It is easy to learn and use. It has been assessed by the NRC to be an acceptable method of assessing line losses, the only code of its type to have this endorsement. By these criteria, it is validated and verified.

Figure 1. Example of a DEPOSITION 2.0 ASCII Output File.

DEPOSITION 2.0: Mon Jun 21 13:22:58 1993

PARTICLE SIZE (μm) -- Vary from 1.000 to 20.000 with 19 Intervals.

Flow Rate (L/min) : 70.000 # of Components : 5 Tube Diam (mm): 26.700
Part Dens (g/cm³): 1.000 FS Velocity (m/s): 3.000 Angle (degrees): 90.000

Element 1 : Isokinetic PROBE
Element 2 : 1.000 m TUBE at 0.000 degrees from Horizontal
Element 3 : 90 degree ELBOW
Element 4 : 0.500 m TUBE at 45.000 degrees from Horizontal
Element 5 : 45 degree ELBOW

Part. Size	Stokes #	Reynolds #	Total Penetration	Element 1 Penetration	Element 2 Penetration	Element 3 Penetration	Element 4 Penetration	Element 5 Penetration
1.000	2.34e-04	3549	99.0 %	99.3 %	99.9 %	99.9 %	100.0 %	99.9 %
2.000	9.37e-04	3549	97.0 %	98.0 %	99.7 %	99.6 %	99.9 %	99.8 %
3.000	2.11e-03	3549	93.9 %	96.1 %	99.4 %	99.0 %	99.8 %	99.5 %
4.000	3.75e-03	3549	90.0 %	93.7 %	98.9 %	98.3 %	99.6 %	99.1 %
5.000	5.86e-03	3549	85.3 %	90.9 %	98.3 %	97.4 %	99.4 %	98.7 %
6.000	8.44e-03	3549	80.0 %	87.6 %	97.5 %	96.2 %	99.1 %	98.1 %
7.000	1.15e-02	3549	74.3 %	84.1 %	96.7 %	94.9 %	98.8 %	97.4 %
8.000	1.50e-02	3549	68.4 %	80.4 %	95.7 %	93.4 %	98.4 %	96.7 %
9.000	1.90e-02	3549	62.4 %	76.6 %	94.5 %	91.8 %	98.0 %	95.8 %
10.000	2.34e-02	3549	56.5 %	72.8 %	93.3 %	90.0 %	97.6 %	94.9 %
11.000	2.84e-02	3549	50.8 %	68.9 %	92.0 %	88.0 %	97.1 %	93.8 %
12.000	3.37e-02	3549	45.3 %	65.2 %	90.5 %	85.9 %	96.5 %	92.7 %
13.000	3.96e-02	3549	40.2 %	61.5 %	88.9 %	83.7 %	95.9 %	91.5 %
14.000	4.59e-02	3549	35.4 %	58.0 %	87.3 %	81.4 %	95.3 %	90.2 %
15.000	5.27e-02	3549	31.0 %	54.7 %	85.5 %	78.9 %	94.6 %	88.9 %
16.000	6.00e-02	3549	27.0 %	51.5 %	83.7 %	76.4 %	93.8 %	87.4 %
17.000	6.77e-02	3549	23.4 %	48.5 %	81.7 %	73.8 %	93.0 %	85.9 %
18.000	7.59e-02	3549	20.1 %	45.6 %	79.7 %	71.2 %	92.2 %	84.4 %
19.000	8.46e-02	3549	17.3 %	43.0 %	77.6 %	68.5 %	91.3 %	82.8 %
20.000	9.37e-02	3549	14.7 %	40.5 %	75.5 %	65.8 %	90.4 %	81.1 %

Figure 2. Example Graph Made from a DEPOSITION 2.0 ASCII File.

Table 1. McFarland Test Cases: Empirical Data and Output of DEPOSITION 2.0 (Fan et al. 1991).

Test cases			Percent penetration	
Flow rate (L/min)	Wind to inlet orientation	Particle dia. (microns)	Empirical data (%)	Obtained from DEPOSITION 2.0 (%)
70	Axial	3.00	100.0	97.1
70	Axial	4.38	98.0	94.7
70	Axial	6.41	93.0	89.9
70	Axial	9.36	83.0	80.8
70	Axial	13.70	68.0	64.5
70	Axial	20.00	31.0	40.0
130	Axial	3.00	97.0	96.4
130	Axial	4.38	93.0	93.1
130	Axial	6.41	87.0	86.5
130	Axial	9.36	73.0	74.1
130	Axial	13.70	46.0	52.5
130	Axial	20.00	8.0	22.4
70	Perpendicular	3.00	96.0	94.4
70	Perpendicular	4.38	92.0	89.3
70	Perpendicular	6.41	82.0	79.5
70	Perpendicular	9.36	63.0	63.2
70	Perpendicular	13.70	31.0	40.4
70	Perpendicular	20.00	5.0	17.6
130	Perpendicular	3.00	95.0	94.4
130	Perpendicular	4.38	92.0	89.1
130	Perpendicular	6.41	86.0	79.0
130	Perpendicular	9.36	72.0	61.5
130	Perpendicular	13.70	38.0	36.5
130	Perpendicular	20.00	5.0	11.6

Table 2. McFarland Test Cases: Empirical Data Versus DEPOSITION 2.0 Output (Fan et al. 1991).

Regression statistics	
Constant	-11.50
Standard error of Y estimate	4.33
R squared	.98
Number of observations	24
Degrees of freedom	22
X coefficients	1.16
Standard error of coefficients	.03
t (for slope = 1)	4.81
Statistics for other criteria	
Average of differences	-0.40
Standard deviation of differences	0.21
t (average/standard deviation of average)	-9.18
Maximum differences	14.4

Table 3. McFarland Test Cases: Empirical Data Verses DEPOSITION 2.0 Output. 20 μ m Aerodynamic Equivalent Diameter Particles Omitted (Fan et al. 1991).

Regression statistics	
Constant	-4.72
Standard error of Y estimate	3.97
R squared	0.96
Number of observations	20
Degrees of freedom	18
X coefficients	1.08
Standard error of coefficients	.05
t (for slope = 1)	1.82
Statistics for other criteria	
Average of differences	-1.43
Standard deviation of differences	4.13
t (average/standard deviation of average)	-1.54
Maximum differences	-10.5

Figure 3. McFarland Tests: Empirical Data Versus
DEPOSITION v2.0 (Fan et al. 1991)

Figure 4. McFarland Tests: Empirical Data Versus
DEPOSITION v2.0 (Fan et al. 1991)
20 micron particles omitted

Table 4. Strom Test Cases: Empirical Data and Output of DEPOSITION 2.0 (Strom 1972).

Test cases		Percent penetration	
Flow rate (L/min)	Particle dia. (microns)	Empirical data (%)	Obtained from DEPOSITION 2.0 (%)
19.65	2.1	95.4	98.6
19.65	4.7	87.1	80.3
19.65	8.0	59.3	53.4
19.65	15.0	11.3	11.1
34.35	2.1	100.5	95.5
34.35	4.7	95.2	80.1
34.35	8.0	70.5	52.7
34.35	15.0	13.8	9.6
61.31	2.1	101.0	93.9
61.31	4.7	90.6	73.5
61.31	8.0	54.7	39.2
61.31	15.0	10.6	1.2

Table 5. Strom Test Cases: Empirical Data Versus Deposition 2.0 Output (Strom 1972).

Regression statistics	
Constant	8.55
Standard error of Y estimate	7.09
R squared	0.96
Number of observations	12
Degrees of freedom	10
X coefficients	1.0
Standard error of coefficients	0.06
t (for slope = 1)	-0.05
Statistics for other criteria	
Average of differences	-8.39
Standard deviation of differences	6.67
t (average/standard deviation of average)	-4.30
Maximum differences	-17.8

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Figure 5. Strom Tests: Empirical Data Versus
DEPOSITION v2.0 (Strom 1972)

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